Solid Earth Discuss.,
https://doi.org/10.5194/se-2020-181-AC1, 2021


# *Interactive comment on* "Reverse time migration (RTM) imaging of iron-oxide deposits in the Ludvika mining area, Sweden" *by* Yinshuai Ding and Alireza Malehmir

**Yinshuai Ding and Alireza Malehmir**

yinshuai.ding@geo.uu.se

Received and published: 18 January 2021

Dear reviewer,

We appreciate your positive feedback. We address your comments point-by-point below. Our revised manuscript will cover these aspects.

The review for "Reverse time migration (RTM) imaging of iron-oxide deposits in the Ludvika mining area, Sweden"

The authors presented an interesting case study with application of Reverse Time Migration which has been rarely practiced in the hard rock environment. The study



provides some clues for those would like to test/improve the method for mineral exploration.

In Figure 2, the authors show their processing flow. Why they did not apply deconvolution to remove seismic source effect. Normally, deconvolution is a crucial step in hard rock environment. The authors need to address if they applied it and if not then why? Is it crucial to preserve the seismic source signature in the shot gathers when RTM is applied?

[Reply: We agree that deconvolution is a crucial step when performing migration algorithms. Though we didn't apply any deconvolution methods to the data in the preprocessing step, the imaging condition in RTM is a deconvolution imaging condition (Claerbout, 1971), which removes the source wavelet approximately, and potentially improves illumination compensation. We add one sentence to make this clear in section 3.3 RTM imaging as below.

'Such a deconvolution imaging condition (Claerbout, 1971) removes the source wavelet approximately and hence improves the resolution of the image.'

Ref: Claerbout, J. F., 1971. Toward a unified theory of reflector mapping: Geophysics, 36, no. 3, 467–481]

In Step 4 offset regularization: How did you apply it. Did you need to pick specific reflection in a shot gather and try to make it up in which to fill the area that the reflection is missing/improve the coherency of the reflection? Or, you applied the linear interpolation filter equally to all shot gather? (We applied it to all the shot gathers equally) Please explain this step in more details. Also, can you discuss the pros/cons of the offset regularization method in hard rock environment?

[Reply: To show how the offset regularization is done, we add one more figure (Figure 4) in our revision. We described regularization in detail in section 3.2 Data Preprocessing as below.

‘The sources and receivers were projected onto a smooth curved profile, which was defined by a third-degree polynomial (Figure 4). Based on the projected receiver locations, we regularized the receiver spacing to a constant interval of 5 m along the 1D-curved profile. The seismic traces at those regularized receiver locations were obtained by a cubic interpolation using the traces at the projected receiver locations. Similarly, we regularized the source locations along the curved profile and obtained the seismic traces at every 5 m interval by a cubic interpolation, which was performed in the common receiver domain.’

The pros/cons of the offset regularization for running RTM is discussed in section 3.3 RTM imaging as below.

‘In this study, we found that the regularized data in the area where receiver spacing was roughly 5 m did not improve the final image, however, the regularized data in the area where receiver spacing was approximately 10 m (southern portion of the seismic profile) provided improved images because the trace density was doubled in this area.’]

Step 5: what is advantage of curvelet filtering method to remove surface waves? Is it working better than median filter? Did you test both filters (i.e., median versus curvelet filter)?

[Reply: In our study, curvelet filtering is used to extract the surface waves in local regions. It is advantageous to only apply filters to a local region where the noise is dominant and leave the data in other regions unaffected.

We tested the median filter as suggested. Using the median filter, the median values were extracted by running a sliding window along several specific slopes and then subtracted from the data. We found that the median filter tends to harm the reflected signals since it is applied globally to the entire data.

We add one figure (Figure 7) showing the RTM image using the median-filtered data while keeping other pre-processing steps unchanged. In the image, we see that the



crosscutting feature is not as obvious as in the RTM image obtained from the curvelet-filtered data.

To remind potential readers that our chosen methods for pre-processing are not unique, we add one sentence in section 3.2 Data Pre-processing as below.

‘Though we chose the specific processing methods in the pre-processing steps to prepare our data for RTM, it is possible to use different methods for pre-processing when done carefully.’]

What is the best procedure to improve the migration velocity model shown in Figure 4? Please explain in more details.

[Reply: There are many ways (e.g., full waveform inversion, reflection/refraction tomography, etc.) to perform a velocity model building. But the velocity model building is limited by the seismic data quality and offsets. As for our dataset, the data is rather noisy for any of these approaches and first arrivals do not sample very deep due to a maximum offset of only 2.5 km. Besides the semblance velocity analysis (which is not so useful for hardrock datasets), we actually tested 10 constant velocity models from 5100 m/s to 6000 m/s with an interval of 100 m/s by running Kirchhoff migrations. Then we found velocity 6000 m/s gave us the best result of the reflections from the mineralization area, which flattens the reflections most in the common image gathers. Based on this constant velocity, we modified the shallow area of the model to make the reflection events in the common image gathers as flat as possible when running RTM. Readers to be reminded that the dataset is already corrected for refraction statics therefore theoretically near-surface low velocities are compensated for at the step of velocity model building.]

In this case study, the straight part of the survey is considered. How do you deal with a crooked survey? Do you think the RTM method is applicable? Please provide more insight about crooked surveys.

[Reply: It is possible to apply RTM along a crooked line if we parameterize the locations of sources and receivers by offsets only. In such a situation, 2D RTM can be run along a crooked line. However, we need to be aware that the strong crooked line may create artifacts in the image, which are difficult to be identified and separated from the true imaged reflectors.

A safer way is to run RTM on several approximately straight segments of the acquisition line independently, then a final image is obtained by merging the images from those segments.]

---

Interactive comment on Solid Earth Discuss., https://doi.org/10.5194/se-2020-181, 2020.